GOLIAD COUNTY GROUNDWATER CONSERVATION DISTRICT
118 S. Market St., P.O. Box 562, Goliad, Texas 77963-0562
Telephone: (361) 645-1716 Facsimile: (361) 645-1772
www.goliadcogcd.org

November 16, 2011

Mr. Philip Dellinger 6WQ-SG
U. S. Environmental Protection Agency
Region 6
Groundwater/UIC Section
1445 Ross Avenue
Suite 1200
Dallas, TX 75202

Mr. Dellinger,

Re: Uranium Energy Corp Request for Aquifer Exemption:

I have enclosed pages from the USGS Report, "Streamflow, Groundwater Hydrology, and Water Quality in the Upper Coleto Creek Watershed in Southeast Texas, 2009-2010." This study was done by USGS in cooperation with Goliad County Groundwater Conservation District, Victoria County Groundwater Conservation District, Pecan Valley Groundwater Conservation District, San Antonio River Authority and Guadalupe Blanco River Authority to study the interaction between surface water and groundwater in this area. We discussed this study with you in the spring of 2011, but because the study was not complete we could not release it to you. It has now been officially released and is available at: http://pubs.usgs.gov/sir/2011/5157/ . If you have any questions about this study please feel free to call Mr. Dohmann at 361-564-2026.
I forwarded the website information to Mr. Jose Torres and asked him to get it to you. I don't have your email address. Thank you again for your consideration in the matter of Goliad County and the application by UEC for an aquifer exemption.

Sincerely, Barbara Smith

Barbara Smith, Manager, GCGCD

RECEIVED
SOURCE WATER
PROTECTION BRANCH
11 NOV 22 AM 8:27
6WQ-S

Barbara Smith

om: Barbara Smith [bsmith@goliadcogcd.org]
ent: Wednesday, November 16, 2011 9:11 AM
To: Torres.Jose@epamail.epa.gov
Subject: FW: Publication Notice SIR 2011-5157 (Coleto Creek Report)

Mr. Torres, Will you please forward this information to Mr. Dellinger and anyone else that would find it useful. Thank you, Barbara Smith, GCGCD, General Manager – Goliad, TX

From: Rebecca B Lambert [mailto:blambert@usgs.gov]
Sent: Monday, October 24, 2011 3:42 PM
To: Dohmann@att.net; Art Dohmann; Barbara Smith; Debbie Magin; Charlotte Krause; Melissa Bryant; tim.andruss@vcgcd.org
Cc: Rebecca B Lambert; Christopher L Braun; Loren L Wehmeyer; James M Null
Subject: re: Publication Notice SIR 2011-5157 (Coleto Creek Report)

Good afternoon--

The Coleto Creek study has been officially approved and released to the public. The report is available online at the URL listed below. Please let me know if you have any questions.

Thanks-

Becky Lambert

Rebecca B. Lambert, P.G.
U.S. Geological Survey
5563 De Zavala Rd., Suite 290
San Antonio, TX 78249
blambert@usgs.gov
(210) 691-9218
(210) 691-9270 FAX

----- Forwarded by Rebecca B Lambert/WRD/USGS/DOI on 10/24/2011 03:28 PM -----

From: David A Perdue/GIO/USGS/DOI

To: GS Online Pub Series Notification Recipients@usgs.gov, GS-I-Pubs-CR Staff ALL, atc@agiweb.org, David R Soller/GD/USGS/DOI@USGS, Janet M Carter/WRD/USGS/DOI@USGS, GS-I-CR RGIO InfoServices@USGS, John P Donnelly/GIO/USGS/DOI@USGS, Betty B Palcsak/WRD/USGS/DOI@USGS, Peter N Schweitzer/GD/USGS/DOI@USGS, Randall C Orndorff/GD/USGS/DOI@USGS, Robert Wardwell/GD/USGS/DOI@USGS, Susan E Quinn/RGIO/USGS/DOI@USGS, ngmdb@yahoo.com, John M Kilpatrick/WRD/USGS/DOI@USGS, Lori K Tuck/WRD/USGS/DOI@USGS, Heidi K Koontz/DO/USGS/DOI@USGS, Gary L Rowe/DO/USGS/DOI@USGS, Lisa A Wald/GD/USGS/DOI@USGS, Bruce Heise/DENVER/NPS@NPS, Marisa Lubeck/DO/USGS/DOI@USGS, Linda J Jacobsen/GD/USGS/DOI@USGS, Gregory K Boughton/WRD/USGS/DOI@USGS, Frank D'Erchia/DO/USGS/DOI@USGS, Cheryl W Adkisson/GD/USGS/DOI@USGS, Christa D Chavez/GD/USGS/DOI@USGS

Cc: Christopher L Braun/WRD/USGS/DOI@USGS, Rebecca B Lambert/WRD/USGS/DOI@USGS

Date: 10/24/2011 12:44 PM

Subject: Science Publishing Network - Publication Notice SIR 2011-5157

Hello,

The following publication was approved for release and has been made available to the public.

Please update listings as needed.

Scientific Investigations Report 2011–5157: Streamflow, Groundwater Hydrology, and Water Quality in the Upper Coleto Creek Watershed in Southeast Texas, 2009–10

http://pubs.usgs.gov/sir/2011/5157/

Thank you,
David

DAVID·A·PERDUE
Electronic Publishing Specialist
U.S. Geological Survey
Publishing Network
Rolla Publishing Service Center
1400 Independence Road
Rolla, Missouri 65401
573-308-3796

It is a fair, even-handed, noble adjustment of things, that while there is infection in disease and sorrow, there is nothing so irresistibly contagious as laughter.
—DICKENS

Streamflow, Groundwater Hydrology, and Water Quality in the Upper Coleto Creek Watershed in Southeast Texas, 2009–10

By Christopher L. Braun and Rebecca B. Lambert

Abstract

The U.S. Geological Survey (USGS), in cooperation with the Goliad County Groundwater Conservation District, Victoria County Groundwater Conservation District, Pecan Valley Groundwater Conservation District, Guadalupe-Blanco River Authority, and San Antonio River Authority, did a study to examine the hydrology and stream-aquifer interactions in the upper Coleto Creek watershed. Findings of the study will enhance the scientific understanding of the study-area hydrology and be used to support water-management decisions to help ensure protection of the Evangeline aquifer and surface-water resources in the study area. This report describes the results of streamflow measurements, groundwater-level measurements, and water quality (from both surface-water and groundwater sites) collected from three sampling events (July–August 2009, January 2010, and June 2010) designed to characterize groundwater (from the Evangeline aquifer) and surface water, and the interaction between them, in the upper Coleto Creek watershed upstream from Coleto Creek Reservoir in southeast Texas. This report also provides a baseline level of water quality for the upper Coleto Creek watershed.

Three surface-water gain-loss surveys—July 29–30, 2009, January 11–13, 2010, and June 21–22, 2010—were done under differing hydrologic conditions to determine the locations and amounts of streamflow recharging or discharging from the Evangeline aquifer. During periods when flow in the reaches of the upper Coleto Creek watershed was common (such as June 2010, when 12 of 25 reaches were flowing) or probable (such as January 2010, when 22 of 25 reaches were flowing), most of the reaches appeared to be gaining (86 percent in January 2010 and 92 percent in June 2010); however, during drought conditions (July 2009), streamflow was negligible in the entire upper Coleto Creek watershed; streamflow was observed in only two reaches during this period, one that receives inflow directly from Audilet Spring and another reach immediately downstream from Audilet Spring. Water levels in the aquifer at this time declined to the point that the aquifer could no longer provide sufficient water to the streams to sustain flow.

Groundwater-level altitudes were measured at as many as 33 different wells in the upper Coleto Creek watershed during three different survey events: August 4–7 and 12, 2009; January 12–14 and 22, 2010; and June 21–24, 2010. These data were used in conjunction with groundwater-level altitudes from three continuously monitored wells to generate potentiometric surface maps for each of the three sampling events to help characterize the groundwater hydrology of the Evangeline aquifer. The altitudes of potentiometric surface contours from all three sampling events are highest in the northeast part of the study area and lowest in the southwest part of the study area. Groundwater flow direction shifts from southeast to east across the watershed, roughly coinciding with the general flow direction of the main stem of Coleto Creek. Groundwater-level altitudes increased an average of 2.35 inches between the first and third sampling events as drought conditions in summer 2009 were followed by consistent rains the subsequent fall and winter, an indication that the aquifer responds relatively quickly to both the absence and relative abundance of precipitation.

A total of 44 water-quality samples were collected at 21 different sites over the course of the three sampling events (August 4–7, 2009, January 12–14, 2010, and June 21–24, 2010). In most cases, samples from each site were analyzed for the following constituents: dissolved solids, major ions, alkalinity, nutrients, trace elements, and stable isotopes (hydrogen, oxygen, and strontium). Major-ion compositions were relatively consistent among most of the samples from the upper Coleto Creek watershed (generally calcium bicarbonate waters, with chloride often making a major contribution). Of the 23 trace elements that were analyzed in water samples as part of this study, only arsenic (in two samples) and manganese (in seven samples) had concentrations that exceeded public drinking-water standards or guidelines. At 3 of the 19 sites sampled—State wells 79-06-411, 79-14-204, and Audilet Spring—nitrate concentrations exceeded the threshold (2.0 milligrams per liter) associated with anthropogenic contributions. The majority of the water samples (36 out of 44) that were analyzed for stable isotopes of hydrogen and oxygen during the three sampling events plotted in a relatively tight cluster centered near the global meteoric water line. The

eight remaining samples, which include the four surface-water samples collected in June 2010, the sample collected from Coleto Creek Reservoir in January 2010, and all three samples collected at State well 79-15-904, deviate from the global meteoric water line in a way that indicates evaporative losses. The isotopic signatures of the three samples collected at State well 79-15-904, when taken in conjunction with its proximity to Coleto Creek Reservoir, indicate that there is likely a hydraulic connection between the two. When all of the sites are examined as a whole, there is a general pattern in strontium concentrations across the entire watershed that indicates that both the surface-water and groundwater samples derive from a single source (the Evangeline aquifer) with relatively uniform water-rock interactions.

Introduction

The U.S. Geological Survey (USGS), in cooperation with the Goliad County Groundwater Conservation District (GCGCD), Victoria County Groundwater Conservation District (VCGCD), Pecan Valley Groundwater Conservation District (PVGCD), Guadalupe-Blanco River Authority (GBRA), and San Antonio River Authority (SARA), did a study to examine the hydrology and stream-aquifer interactions in the upper Coleto Creek watershed (fig. 1). Findings of the study will enhance the scientific understanding of the study-area hydrology and be used to support water-management decisions for the Evangeline aquifer and surface-water resources in the study area.

The data documented in this report will provide baseline information to address different hydrologic and water-quality issues in a coastal study area undergoing changes in land use, such as possible streambank erosion, loss of wetlands, subsidence, saltwater intrusion, problems associated with excessive nutrients, disease-causing microorganisms, and toxic chemicals originating from industrial activities or mining practices.

Purpose and Scope

The purpose of this report is to describe streamflow, groundwater-level altitudes, and water quality (from both surface-water and groundwater sites) from three sampling events (July–August 2009, January 2010, and June 2010) in order to characterize surface water, groundwater from the Evangeline aquifer, and the interaction between them, in the upper Coleto Creek watershed upstream from Coleto Creek Reservoir in southeast Texas.

Description of Study Area

The upper Coleto Creek watershed (fig. 1) is mostly rural and, like other areas of Texas, is experiencing population growth (U.S. Census Bureau, 2011); as a whole, the three counties that make up the study area (De Witt, Goliad, and Victoria) experienced slightly less than a 3 percent population increase between 2000 and 2009. The upper Coleto Creek watershed starts about 12 miles (mi) northwest of Yorktown and ends at Coleto Creek Reservoir. Coleto Creek Reservoir, which is used primarily to provide cooling water for electric power generation, is about 12 mi southwest of Victoria on Coleto and Perdido Creeks and impounds runoff from 507 square miles (mi^2) of drainage area (Guadalupe-Blanco River Authority, 2007). Conservation storage for the reservoir is 31,040 acre-feet (Texas Water Development Board, 2011).

The upper Coleto Creek watershed overlies the Texas coastal lowlands aquifer system (Chicot, Evangeline, and Jasper aquifers). The Texas coastal lowlands aquifer system is equivalent to the Gulf Coast aquifer system (Ashworth and Hopkins 1995; Kasmarek and Robinson, 2004). The Texas coastal lowlands aquifer system is composed of formations from Oligocene through Holocene age (fig. 2) that dip and thicken toward the Gulf of Mexico. The sediments composing the Texas coastal lowlands aquifer system consist of overlapping mixtures of sand, silt, and clay deposited and reworked by numerous oscillations of ancient shorelines (Ryder, 1996; Lizárraga and Ockerman, 2010). The Jasper aquifer crops out (that is, becomes exposed at land surface) in the northwest corner of the study area; the following hydrogeologic units crop out successively towards the southeast corner of the study area: Burkeville confining unit, Evangeline aquifer, and Chicot aquifer (fig. 3). Geologic units corresponding with each hydrogeologic unit are shown in figure 2.

The Evangeline aquifer, which is the principal aquifer of interest in this study, is typically wedge shaped (because it dips and thickens toward the coast) and has a high sand-clay ratio; it contains individual sand beds that are characteristically tens of feet thick (Baker, 1979). The aquifer ranges in thickness from 400 to 1,000 feet (ft) where it crops out (the surface expression is shown in fig. 3). Near the coastline, where the top of the aquifer is about 1,000 ft deep, its thickness averages about 2,000 ft (Baker, 1979). The Evangeline is considered one of the most prolific producing aquifers in the Texas Coastal Plain and is known for its abundance of good-quality groundwater (Baker, 1979).

The climate of the study area is described as subtropical humid and is characterized by warm summers and mild winters (Larkin and Bomar, 1983). Heaviest precipitation tends to occur in late spring to early summer and in the fall (Texas Water Development Board, 2007); droughts and floods are common.

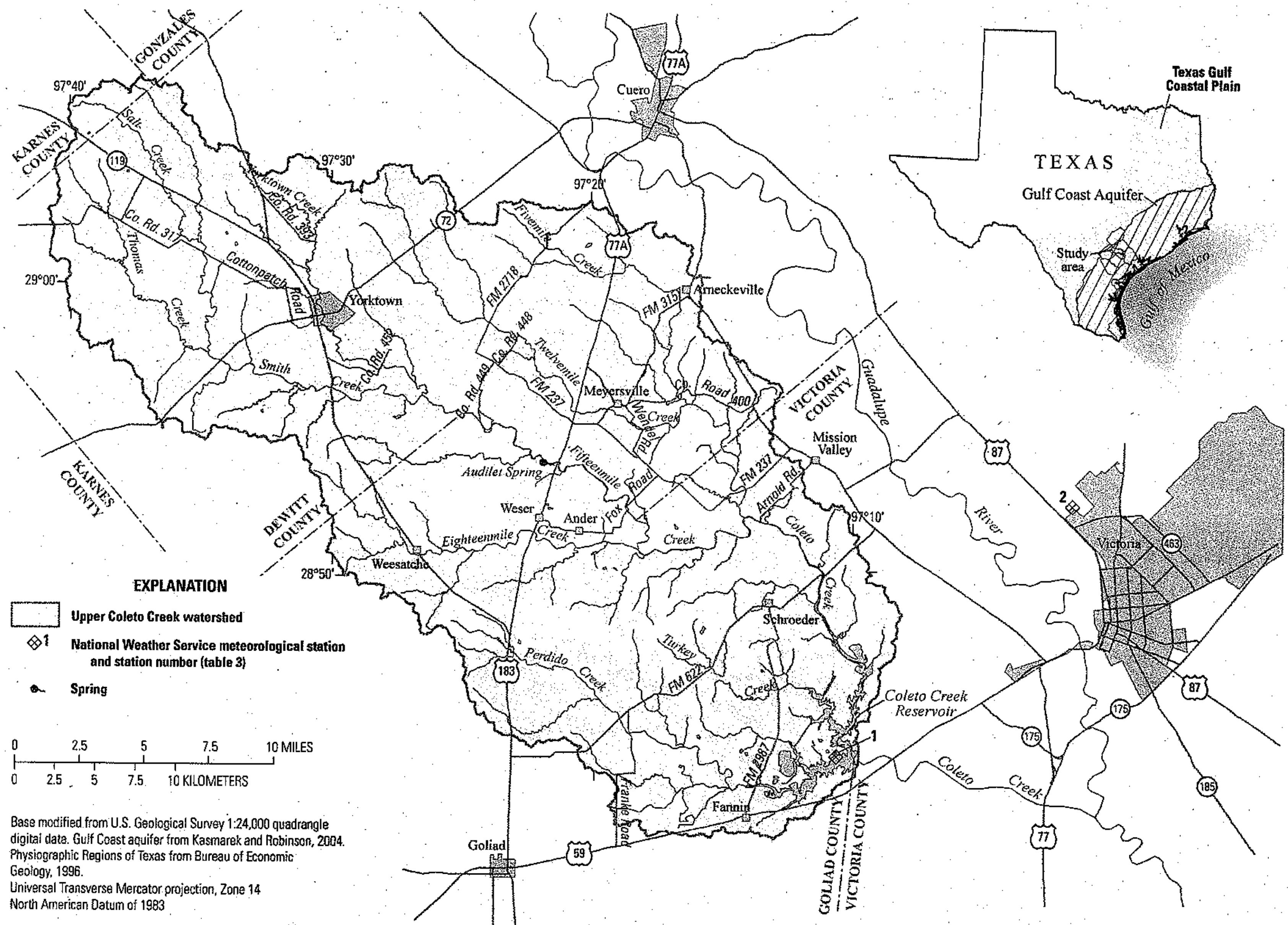

Figure 1. Location of study area.

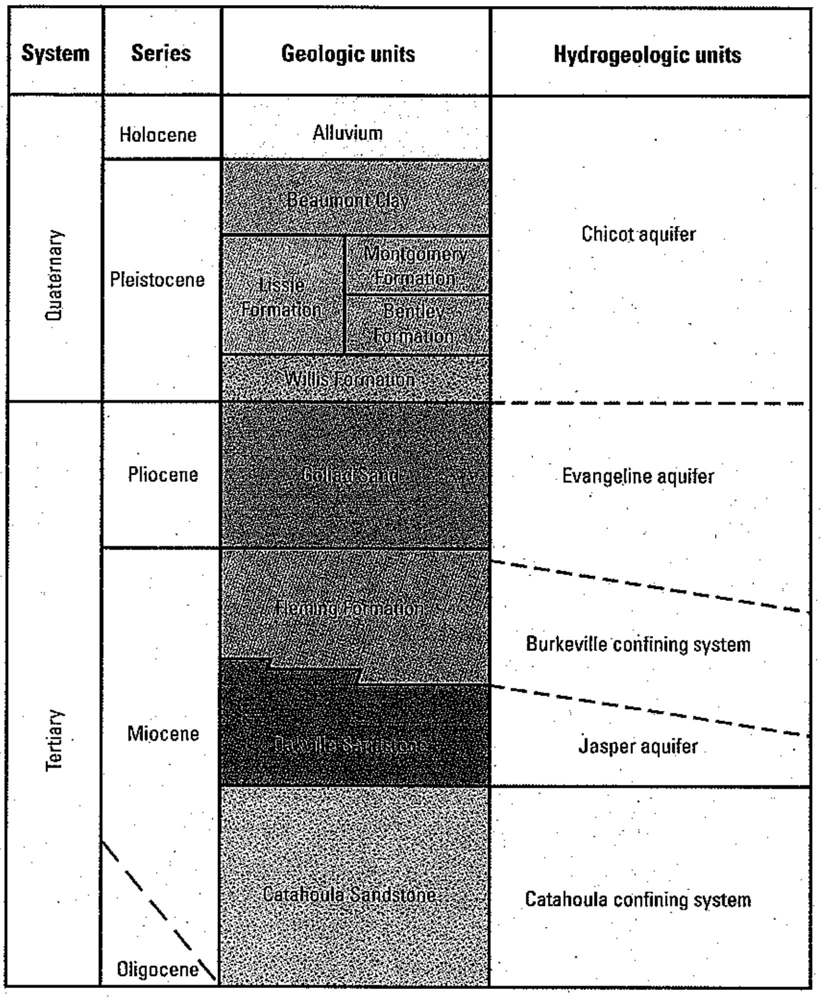

Figure 2. Geologic and hydrogeologic units of the Texas coastal lowlands aquifer system in the upper Coleto Creek watershed in southeast Texas (modified from Baker, 1979, table 1, and Mace and others, 2006, fig. 2–12).

Methods of Study

Site Selection

Surface-water sites were selected as part of the initial, broad-based inventory (table 1, fig. 4) on the basis of their accessibility (typically adjacent to public roads, thereby eliminating the need for permission to access private land), position relative to where the Evangeline aquifer crops out, potential contribution to streamflow of the upper Coleto Creek watershed (larger, perennial streams were given priority over smaller, intermittent ones), and location within the study area relative to existing USGS streamflow-gaging stations and to the other surface-water sites identified during the inventory. A subset of the surface-water sites from the broad-based inventory was selected for the gain-loss survey. Sites were selected that provided the greatest potential for streamflow during variable (wet and dry) hydrologic conditions, as well as the most information regarding streamflow gains from or losses to the Evangeline aquifer. Sites at or just below the confluence of two streams, which were considered to be major contributors to streamflow in the study area, also were selected whenever possible. Surface-water sites were selected for water-quality analyses on the basis of potential for perennial flow and proximity to groundwater sites selected for water-quality analyses in order to allow for comparison of water quality between the two.

Available monitoring wells completed in the Evangeline aquifer in the study area were inventoried with assistance from the cooperating agencies (GCGCD, VCGCD, PVGCD, GBRA, SARA) to identify suitable wells for monitoring and water-quality sampling. Approximately 75 percent of the selected wells were within a 1-mi buffer zone around Coleto Creek and its major tributaries; a few additional wells along Perdido Creek were also identified. Information from the

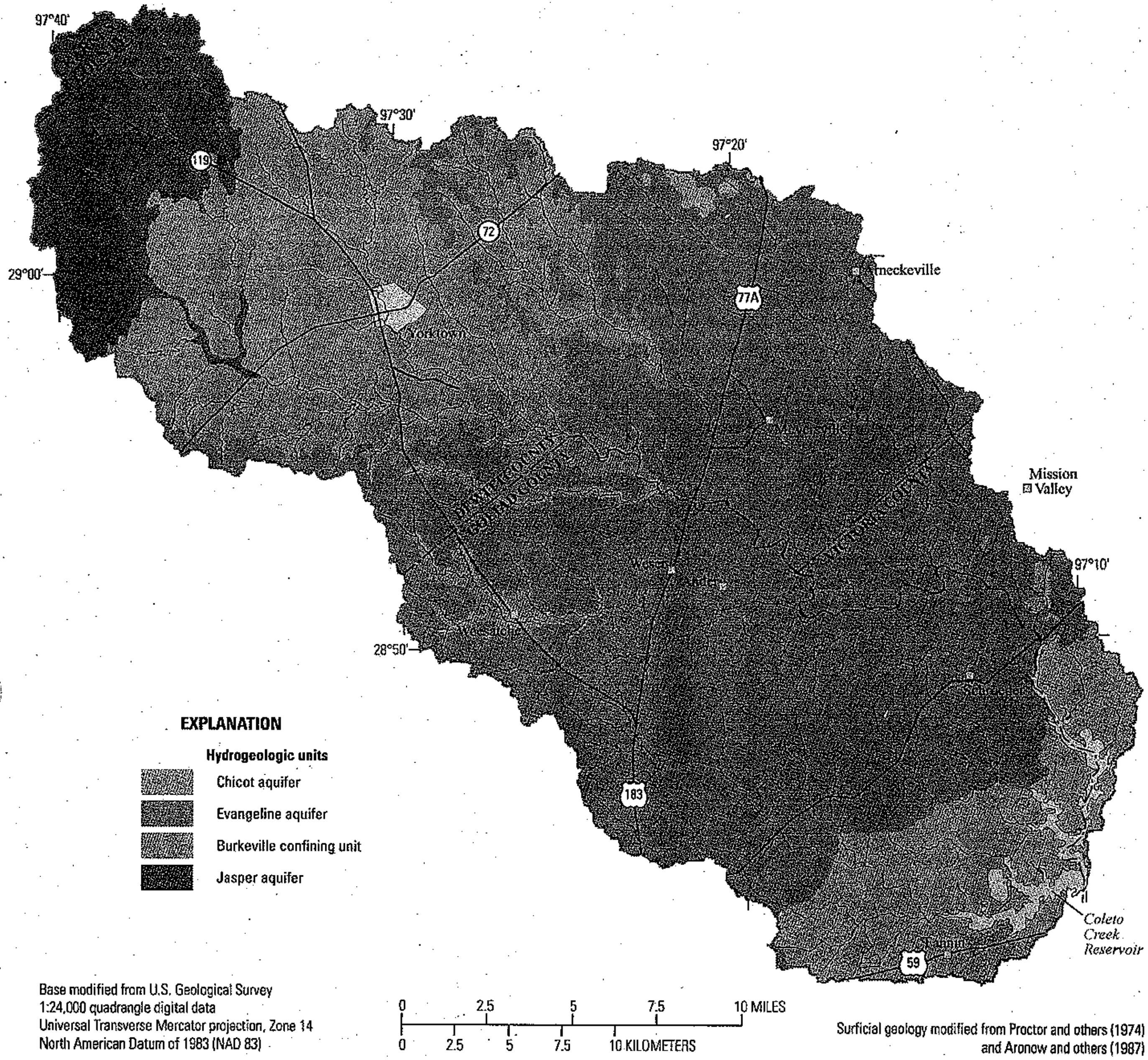

Figure 3. Hydrogeologic units in the upper Coleto Creek watershed, southeast Texas.

initial broad-based well inventory culminated in the selection of 37 existing State wells (fig. 4). Of the selected wells, four were chosen because of their proximity to each of the four surface-water sites selected for water-quality analyses, whereas some wells were selected because they were farther from streams and represented aquifer conditions that were less likely to be influenced by streamflow. Wells were also selected to provide a good spatial distribution across the study area. Both shallow and deep Evangeline aquifer wells were selected for the study. No wells were selected where the Jasper aquifer crops out in the northwest corner of the upper Coleto Creek watershed (fig. 3), because the Evangeline aquifer is absent in this area. Depth to water, well depth, discharge, general construction information, aquifer(s) penetrated, and location were determined for each of the wells inventoried whenever possible. This information was compiled, reviewed, and entered into the USGS National Water Information System (NWIS) database (U.S. Geological Survey, 2011).

Table 1. Description of surface-water sites in the upper Coleto Creek watershed, southeast Texas, July 2009–June 2010.

[USGS, U.S. Geological Survey; x, measurement made; M, miscellaneous streamflow measurement site; C, continuous streamflow measurement site; R, reservoir-stage gaging station]

Site identifier (figs. 4, 6, 12–15)	USGS station number	USGS station name	Site type	Data type	County	Gain-loss survey			Water-quality sampling		
						July 2009	January 2010	June 2010	August 2009	January 2010	June 2010
1	08176523	Salt Creek at County Road 317 near Yorktown, Tex.	M	Streamflow	De Witt	x	x	x			
11	08176526	Thomas Creek at Cottonpatch Road near Yorktown, Tex.	M	Streamflow	De Witt	x	x	x			
13	08176529	Smith Creek at Highway 72 near Yorktown, Tex.	M	Streamflow	De Witt	x	x	x			
14	08176532	Smith Creek at Highway 119 near Yorktown, Tex.	M	Streamflow	De Witt	x	x	x			
2	08176535	Yorktown Creek at County Road 393 near Yorktown, Tex.	M	Streamflow	De Witt	x	x	x			
12	08176538	Yorktown Creek at Highway 72 at Yorktown, Tex.	M	Streamflow	De WItt	x	x	x			
23	08176540	Yorktown Creek at County Road 452 near Yorktown, Tex.	M	Streamflow	De Witt	x	x	x		x	x
26	08176544	Fifteenmile Creek at County Road 449 Road near Ander, Tex.	M	Streamflow	Goliad	x	x	x			
44	08176548	Fifteenmile Creek at Audilet Crossing near Ander, Tex.	M	Streamflow	DeWitt		x				
46	08176550	Fifteenmile Creek near Weser, Tex.	M	Streamflow	DeWitt	x	x	x			
76	08176555	Fifteenmile Creek at Fox Road near Ander, Tex.	M	Streamflow	Goliad	x	x	x			
62	08176565	Eighteenmile Creek at Highway 119 at Weesatche, Tex.	M	Streamflow	Goliad	x	x	x			
70	08176580	Eighteenmile Creek at Highway 77A/183 near Ander, Tex.	M	Streamflow	Goliad	x	x	x			
80	08176590	Fifteenmile Creek below Eighteenmile Creek near Ander, Tex.	M	Streamflow	Goliad		x	x		x	x
79	08176592	Fifteenmile Creek near Ander, Tex.	M	Streamflow	Goliad	x	x				
20	08176594	Twelvemile Creek at Farm Road 2718 near Yorktown, Tex.	M	Streamflow	De Witt	x	x	x			
34	08176596	Twelvemile Creek at Highway 77A/183 near Meyersville, Tex.	M	Streamflow	De Witt	x	x	x			
51	08176598	Twelvemile Creek at Wendel Road near Meyersville, Tex.	M	Streamflow	De Witt	x	x	x			
9	08176599	Fivemile Creek at Highway 77A/183 near Arneckville, Tex.	M	Streamflow	De Witt	x	x	x			
32	08176675	Fivemile Creek at Farm Road 3157 near Arneckville, Tex.	M	Streamflow	De Witt	x	x	x			
37	08176750	Fivemile Creek at County Road 400 near Meyersville, Tex.	M	Streamflow	De Witt	x	x	x			
55	08176825	Twelvemile Creek at Farm Road 237 near Mission Valley, Tex.	M	Streamflow	Victoria	x	x	x			
90	08176900	Coleto Creek at Arnold Road Crossing near Schroeder, Tex.	C	Streamflow	Goliad	x	x	x		x	x
97	08177000	Coleto Creek near Schroeder, Tex.	M	Streamflow	Victoria	x	x	x			
99	08177270	Turkey Creek at Farm Road 2987 near Fannin, Tex.	M	Streamflow	Goliad	x	x	x			
87	08177300	Perdido Creek at Farm Road 622 near Fannin, Tex.	C	Streamflow	Goliad	x	x	x		x	x
101	08177310	Perdido Creek at Franke Road near Fannin, Tex.	M	Streamflow	Goliad	x					
104	08177350	Perdido Creek at Farm Road 2987 near Fannin, Tex.	M	Streamflow	Goliad	x	x	x			
106	08177400	Coleto Creek Reservoir near Victoria, Tex.	R	Reservoir stage	Victoria	x	x	x		x	

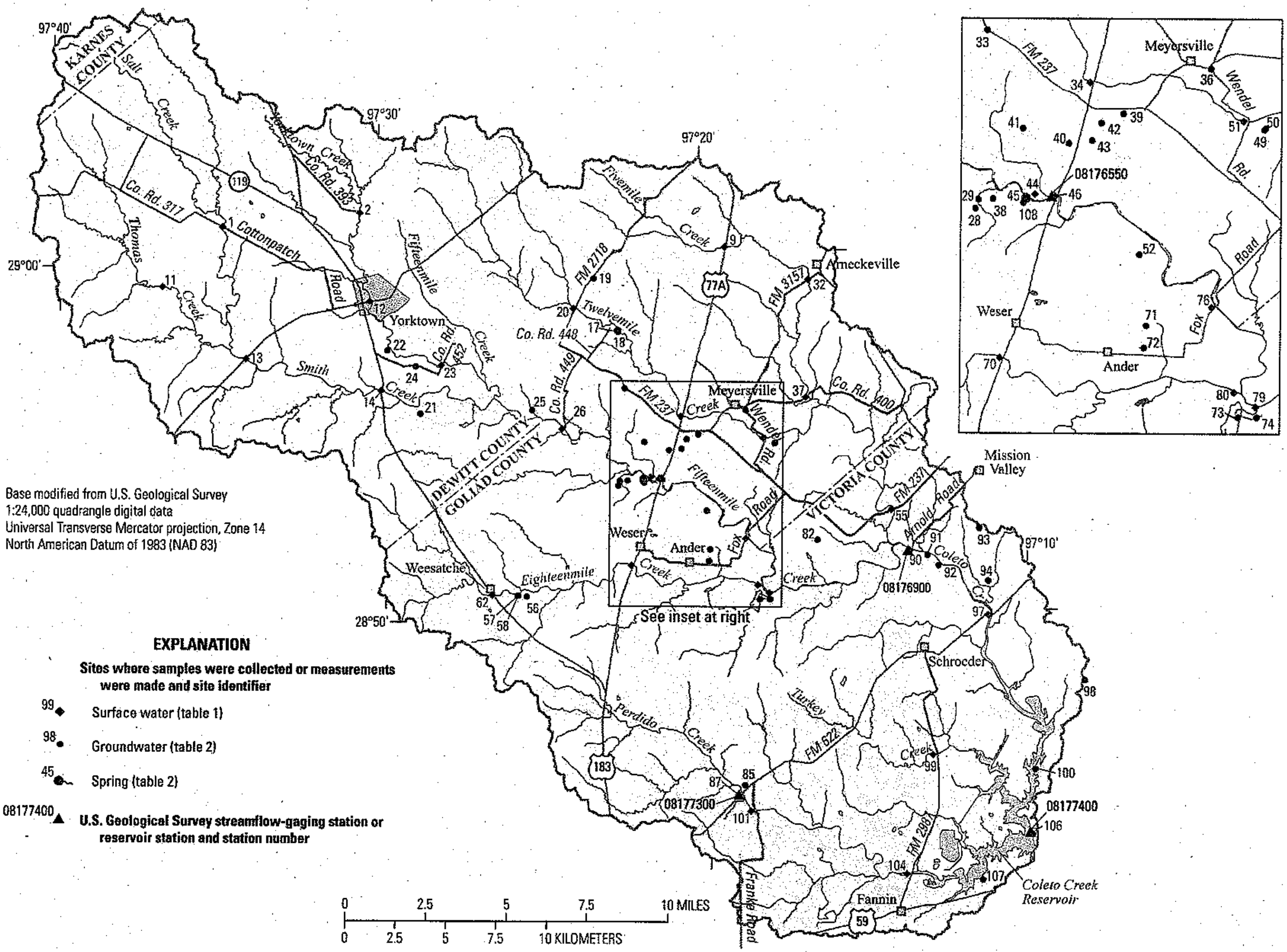

Figure 4. Locations of all sites where samples were collected or measurements were made in the upper Coleto Creek watershed, southeast Texas.

Streamflow: Synoptic Gain-Loss Surveys and Gaged Data

Three surface-water gain-loss surveys were done in different seasons with differing hydrologic conditions—summer 2009 (July 29–30), winter 2010 (January 11–13), and again in summer 2010 (June 21–22)—to more accurately determine the seasonal variation, locations, and magnitude of stream-aquifer interaction. Methods used to measure streamflow (discharge) amounts during each gain-loss survey are described in detail by Rantz and others (1982). The results of the gain-loss assessments in this study are intended to provide initial information to improve the understanding of the study-area hydrology, but these results will not be adequate for broad characterization of gaining and losing streamflow over all hydrologic regimes, nor can they be extrapolated over time. Synoptic streamflow measurements were made at 25 surface-water measurement sites during each of the three gain-loss surveys (table 1, fig. 4). Streamflow measurements were made in one or two of the three gain-loss surveys at three alternate measurement sites (USGS stations 08176548 Fifteenmile Creek at Audilet Crossing near Ander, Tex., 08176590 Fifteenmile Creek below Eighteenmile Creek near Ander, Tex., and 08177310 Perdido Creek at Franke Road near Fannin, Tex.). These alternate sites were used to verify results collected at the primary sites or as a check for flow in a site upstream from a primary site that had no flow. Streamflow measurements were made in two of the three gain-loss surveys at one site (USGS station 08176592 Fifteenmile Creek near Ander, Tex.).

Streamflow data collected during June 1, 2009–June 30, 2010, from two USGS streamflow-gaging stations in the upper Coleto Creek watershed (08176900 Coleto Creek at Arnold Road Crossing near Schroeder, Tex. [hereinafter station 08176900 on Coleto Creek] and 08177300 Perdido Creek at Farm Road 622 near Fannin, Tex. [hereinafter station 08177300 on Perdido Creek]) provided additional data points (for the time periods between gain-loss surveys) for the assessment of gaining and losing reaches. Streamflow measurements were made about every 2 months during the study at the two streamflow-gaging stations, and continuous streamflow records are computed from the stage, or gage height, which is measured every 60 minutes by using a pressure transducer or radar equipment. An analysis of potential measurement error for the rated streamflow values has been included in the gain-loss calculations that include rated streamflow from existing streamflow-gaging stations (discussed in the "Gain-Loss Streamflow Measurements" section).

Water-Level-Altitude Measurements

Using methods described by Cunningham and Schalk (2011), depth to groundwater was measured at as many as 33 different State wells in the upper Coleto Creek watershed with either a steel tape or an electronic water-level contact tape (e-line) three separate times: (1) August 4–7 and 12, 2009; (2) January 12–14 and 22, 2010; and (3) June 21–24, 2010. At some sites, water levels might not have been measured for one of the following reasons: the well was being pumped at the time of the site visit, the field technician was unable to obtain permission to access the well, or the well was not incorporated into the network until after the first round of sampling. The depth to groundwater data were used to generate potentiometric surface maps for each of the three rounds of data collection. Water-level altitudes (WLAs) were subsequently computed by subtracting depth to water at each sampling location from ground-surface elevation at that location; ground-surface elevations were obtained by intersecting well locations with land-surface altitudes derived from the USGS National Digital Elevation dataset (Gesch, 2007). These data were used in conjunction with WLAs (when available) from three wells, which are continuously monitored for WLAs by the Texas Commission on Environmental Quality (TCEQ). Data from the three TCEQ wells used for this report were entered into the NWIS database (U.S. Geological Survey, 2011). Of the three monitoring wells operated by TCEQ, two were deactivated by TCEQ after the first sampling event (State wells 79-05-505 and 79-15-604 were deactivated on October 18, 2009, and November 4, 2009, respectively), but the third (State well 79-13-224) was active throughout the course of the study. USGS station numbers corresponding to all State well numbers used in this report are listed in table 2.

Water-Quality Sample Collection

A total of 44 water-quality samples were collected at 21 sites over the course of the three sampling events (August 4–7, 2009, January 12–14, 2010, and June 21–24, 2010). However, all sites were not sampled for all chemical constituents during all three sampling events. Stable isotope samples for hydrogen and oxygen were collected at all 21 sites. Physical properties (dissolved oxygen, pH, specific conductance, temperature, and turbidity) were measured onsite using a YSI handheld multiparameter meter at all sites except USGS station 08177400 Coleto Creek Reservoir near Victoria, Tex., (hereinafter the Coleto Creek Reservoir site). Water-quality samples collected from all surface-water sites (table 1), and from Audilet Spring and the groundwater sampling sites (with the exception of those collected from State well 79-23-205 and the Coleto Creek Reservoir site; table 2) were analyzed for dissolved solids, major ions, alkalinity, nutrients, trace elements, and the stable isotope of strontium. Samples collected from State well 79-23-205 and the Coleto Creek Reservoir site were analyzed for hydrogen and oxygen stable isotope analyses exclusively. Of the 19 sites analyzed for a full suite of constituents, 4 were surface-water sites (streams) and the remaining 15 were groundwater sites (wells).

The four stream sites selected for water-quality analyses (USGS stations 08176540 Yorktown Creek at County Road 452 near Yorktown, Tex., 08176590 Fifteenmile Creek below Eighteenmile Creek near Ander, Tex., 08176900 on Coleto

Table 2. Description of groundwater and spring sites in the upper Coleto Creek watershed, southeast Texas, August 2009–June 2010.

[USGS, U.S. Geological Survey; x, measurement made]

Site identifier (figs. 4, 6, 12–15)	USGS station number	State well number	Site type	County	Water-level measurement			Water-quality sampling		
					August 2009	January 2010	June 2010	August 2009	January 2010	June 2010
17	285750097224001	79-05-303	Groundwater	DeWitt	x	x	x	x		
18	285752097224201	79-05-304	Groundwater	DeWitt		x	x			
19	285919097232301	79-05-305	Groundwater	DeWitt		x	x			
21	285541097285301	79-05-407	Groundwater	DeWitt	x	x	x			
22	285726097295301	79-05-406	Groundwater	DeWitt	x	x	x			
24	285658097290101	79-05-408	Groundwater	De Witt	x	x	x	x	x	x
25	285543097252301	79-05-505	Groundwater	De Witt	x					
28	285337097224301	79-05-903	Groundwater	Goliad	x	x	x			
29	285344097224001	79-05-904	Groundwater	Goliad	x	x	x			
33	285616097222801	79-06-411	Groundwater	DeWitt	x	x	x	x	x	x
36	285537097184201	79-06-506	Groundwater	De Witt	x	x	x			
38	285345097222501	79-06-712	Groundwater	Goliad	x	x	x			
39	285459097201101	79-06-703	Groundwater	DeWitt	x	x	x			
40	285434097191901	79-06-807	Groundwater	DeWitt	x	x	x			
41	285445097215301	79-06-709	Groundwater	DeWitt	x	x	x	x		
42	285451097203401	79-06-710	Groundwater	DeWitt	x	x	x			
43	285435097204301	79-06-707	Groundwater	DeWitt	x	x				
49	285443097174801	79-06-808	Groundwater	DeWitt	x	x	x	x	x	x
50	285443097174802	79-06-809	Groundwater	DeWitt	x	x				
52	285254097195801	79-06-810	Groundwater	Goliad	x	x	x	x		
56	285037097253901	79-13-231	Groundwater	Goliad		x	x			
57	285038097255402	79-13-224	Groundwater	Goliad	x		x			
58	285038097255401	79-13-225	Groundwater	Goliad	x	x	x			
71	285149097195201	79-14-204	Groundwater	Goliad	x	x	x	x	x	x
72	285129097195401	79-14-202	Groundwater	Goliad	x	x	x			
73	285025097182101	79-14-205	Groundwater	Goliad	x	x	x	x	x	x
74	285025097180201	79-14-203	Groundwater	Goliad	x		x			
82	285203097163001	79-14-303	Groundwater	Victoria	x	x	x			
85	284518097185401	79-14-804	Groundwater	Goliad	x	x	x	x	x	x
91	285134097130601	79-15-101	Groundwater	Goliad	x	x	x	x	x	x
92	285116097124501	79-15-102	Groundwater	Goliad	x	x	x			
93	285216097112801	79-15-205	Groundwater	Victoria	x	x	x	x		
94	285049097111201	79-15-206	Groundwater	Victoria	x	x	x	x		
98	284801097081601	79-15-604	Groundwater	Victoria	x					
100	284535097095101	79-15-904	Groundwater	Victoria	x	x	x	x	x	x
107	284240097112201	79-23-205	Groundwater	Victoria					x	
108	285345097215201	79-06-713	Groundwater	DeWitt		x	x		x	x
45	285354097215401	79-06-711 (Audilet Spring)	Spring	Goliad				x	x	x

Creek, and 08177300 on Perdido Creek [table 1, fig. 4]) were not flowing when the sites were visited during August 2009, so five alternate sites (wells) were sampled in their place (State wells 79-15-206, 79-15-205, 79-06-810, 79-06-709, and 79-05-303, respectively). Because the streams were flowing past the four streamflow-gaging stations during the two subsequent sampling events, the five alternate sites were sampled only once (August 2009), and the four stream sites were sampled two times each (January 2010 and June 2010). Samples were collected only once (during January 2010) from the Coleto Creek Reservoir site and from State well 79-23-205, whereas State well 79-06-713 was sampled twice, in January 2010 and June 2010. The nine remaining sites (all wells) were each sampled during all three sampling events.

Water-quality samples were collected, processed, and preserved in accordance with standard USGS methods documented in the "National Field Manual for the Collection of Water-Quality Data" (U.S. Geological Survey, variously dated). In preparation for the collection of groundwater samples, all wells were pumped until the physical properties stabilized prior to sample collection and processing. Surface-water sampling was also predicated on field-measurement stabilization prior to sample collection and processing. Physical properties were considered stable when the variation between five or more sequential field-measurement readings was less than 0.3 milligram per liter (mg/L) for dissolved oxygen, 5 percent for specific conductance, 0.05 unit for pH, and 0.2 degrees Celsius for temperature. Groundwater and surface-water samples were collected at each site in a 2-liter Teflon bottle, which was then subsampled into the appropriate bottles for the desired analyses at the site in question.

Analytical Methods

Using the inflection point method, alkalinity was determined at the time of sample collection by titration of 50 mL of filtered sample with 1.6-normal sulfuric acid to a pH of less than 4.0 (Rounds, 2006). All samples had negligible hydroxide and carbonate concentrations, so these ions were not considered in this report. The water-quality samples were analyzed for major ions, nutrients, trace elements, and selected stable isotopes. Water samples were analyzed in accordance with approved methods by the USGS National Water Quality Laboratory (NWQL) in Denver, Colo., for major ions (Fishman and Friedman, 1989; Fishman, 1993), nutrients (Fishman, 1993; Patton and Truitt, 2000), and trace elements (Fishman and Friedman, 1989; Garbarino, 1999; and Garbarino and others, 2006).

Samples for stable isotopes of hydrogen and oxygen were analyzed by the USGS Stable Isotope Laboratory in Reston, Va. (Epstein and Mayeda, 1953; Coplen and others, 1991). Stable isotopes are reported as the ratio of the two most abundant isotopes of a given element. The most abundant isotopes of hydrogen are hydrogen-2 (^{2}H), which is also referred to as deuterium (D), and hydrogen-1 (^{1}H), which is also referred to as protium. The most abundant isotopes of oxygen are oxygen-18 (^{18}O) and oxygen-16 (^{16}O) (Clark and Fritz, 1997). Water molecules with a larger percentage of the lighter hydrogen and oxygen isotopes (^{1}H and ^{16}O, respectively) evaporate preferentially compared to water molecules with a larger percentage of the heavier hydrogen and oxygen isotopes (^{2}H and ^{18}O, respectively) (Bruckner, 2009). Stable isotope analysis results for $^{2/1}H$ and $^{18/16}O$ are reported as δD and $\delta^{18}O$, respectively, each of which represents the relative difference in parts per thousand (per mil) between the sample isotope ratio and the isotope ratio of a known standard (Kendall and McDonnell, 1998). The ratios of naturally occurring, stable isotopes of strontium (strontium-87/strontium-86, also notated $\delta^{87}Sr/\delta^{86}Sr$) were determined by the USGS National Research Program Laboratory in Menlo Park, Calif., in accordance with approved methods (Bayless and others, 2004).

Quality Assurance

Quality control (QC) samples were collected to ensure the quality, precision, accuracy, and completeness of the water-quality dataset. Water-quality samples were collected and processed by following the procedures documented in the USGS National Field Manual (U.S. Geological Survey, variously dated). One equipment blank was collected on August 10, 2009, and sequential-replicate samples were collected on August 5, 2009 (State well 79-06-411), and on January 11, 2010 (State well 79-14-804); these results are listed in appendix 1. The equipment blank was analyzed for major ions, nutrients, and trace elements; replicate samples were analyzed for major ions, nutrients, trace elements, and stable isotopes (δD, $\delta^{18}O$, and $\delta^{87}Sr/\delta^{86}Sr$).

As noted by Fleming and others (2011, p. 18), "the accuracy of major dissolved-constituent values in a reasonably complete chemical analysis of a water sample can be checked by calculating the cation-anion balance (Hem, 1985). If the analytical work has been performed accurately, and if all major ions were analyzed, the difference between the two sums will generally not exceed approximately plus or minus 5 percent." Additional quality-control checks of ionic balances revealed the analyses for some constituents were suspect for samples collected at two of the wells. The cation-anion balance of samples collected August 6, 2009, at State well 79-15-101 exceeded the plus or minus 5 percent criterion (the cation concentrations were all markedly smaller compared to the anion concentrations, possibly because the deionized water used to rinse the filter had not been completely evacuated prior to filling the sample bottle) and the cation concentrations were judged erroneous by the authors. In addition, alkalinity for the sample collected at State well 79-15-904 on June 21, 2010, was judged erroneously low; there were no corroborating data (such relatively low concentrations of other anions or cations) to substantiate the validity of this alkalinity value. The cation data collected August 6, 2009, from State well 79-15-101 and alkalinity measured June 21, 2010, from